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New Species of Late Cretaceous Cypraeacea (Mollusca: Gastropoda) from California and Mississippi, and a Review of Cretaceous Cypraeaceans of North America

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Abstract. Cypraeacean mollusks are rare in Cretaceous deposits of North America. Only 15 species are recognized, of which four are new and are described herein. Six species of *Palaeocypraea* s.s. have been previously described, and *Palaeocypraea* (P.) *fontana* (Anderson, 1958) from the Lower Cretaceous (uppermost Lower Albian), Budden Canyon Formation, Shasta County, California, is the earliest known cypraeacean from the Western Hemisphere. *Bernaya* s.s. is represented by two species and *Bernaya* (*Protocypraea*) comprises five species. *Eocypraea* s.s. is represented by two species.

New species described herein are as follows: *Bernaya* (B.) *crawfordcatei* from the Upper Cretaceous (Campanian/Maastrichtian), Point Loma Formation, San Diego County, California; *Bernaya* (*Protocypraea*) *mississippiensis* from the Upper Cretaceous (Campanian), Coffee Formation, Lee County, Mississippi; *B.* (P.) *rineyi* from the Upper Cretaceous (Campanian/Maastrichtian), Point Loma Formation, San Diego County, California; and *Eocypraea* (E.) *louellae* from the Upper Cretaceous (Turonian), Yolo Formation, Yolo County, California. *Eocypraea* (E.) *louellae* is the earliest known ovulid from the Western Hemisphere.

INTRODUCTION

Four new species of cypraeacean gastropods, rare in Cretaceous deposits of North America, are described from localities in San Diego and Yolo counties, California, and Lee County, Mississippi (Figure 1). Two of the new species are from the Upper Cretaceous (Campanian/Maastrichtian), Point Loma Formation (Rosario Group), near Carlsbad, northern San Diego County, southern California; the third is from the Upper Cretaceous (Turonian), Yolo Formation of the Great Valley Series, Yolo County, northern California. A fourth new species is from the Upper Cretaceous (Campanian), Coffee Formation (Selma Group), Lee County, northeastern Mississippi. This paper describes and illustrates these new species as well as illustrating and providing a brief synopsis of the previously described North American cypraeacean species.

Historical Review

The first cypraeacean species described from the Cretaceous of North America was *Cypraea mortoni* Gabb, 1860. *Cypraea squyeri* Campbell, 1893, from Montana and a similar species, *Cypraea suciensis* Whiteaves, 1895, from Sucia Island, Washington, were subsequently described. SCHILDER (1932) separated species from Alabama and New Jersey, both previously considered to be *Cypraea mortoni*, and proposed *Palaeocypraea burlingtonensis* for the New Jersey species. In a survey of the Navarro Group of Texas, STEPHENSON (1941) described two new species: *Cypraea nuciformis* and *Cypraea gracilis* (*Cypraea gracilis* Stephenson, preoccupied, was subsequently renamed *Cypraea corsicanana* Stephenson, 1948). INGRAM (1942, 1947a, b) included Cretaceous species in his reviews of North American fossil and living cypraeaceans. ANDERSON (1958)

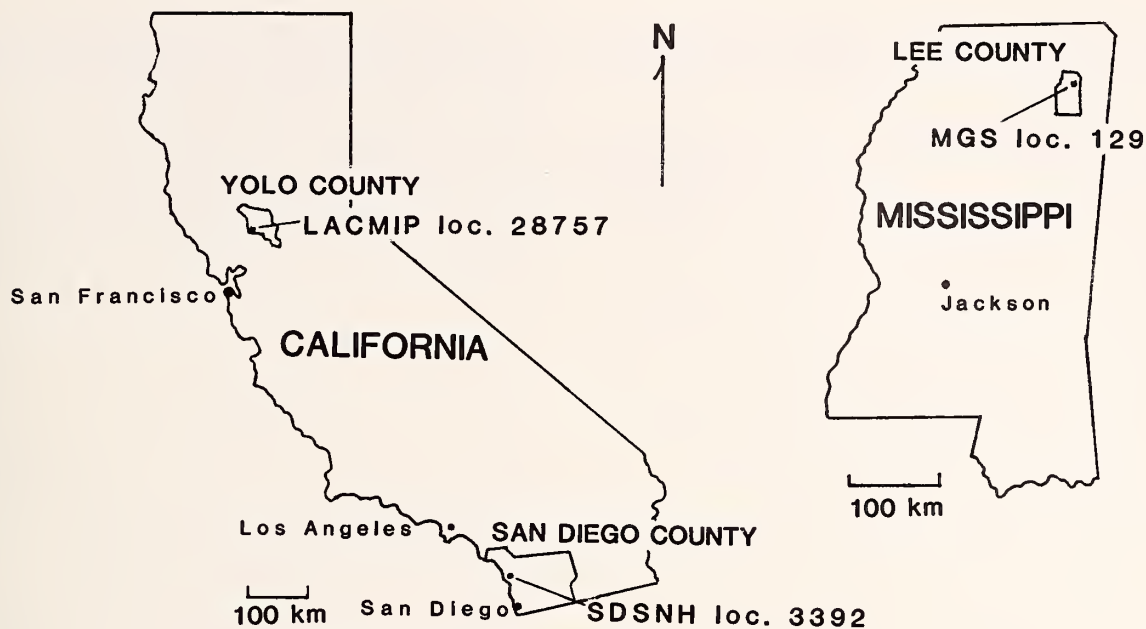


Figure 1

Index maps showing locations of type localities of new species of Cretaceous cypraeids described herein. Localities listed are described in the Appendix—Localities Cited.

described *Cypraea gualalaensis*, *Cypraea berryessae*, and *Cypraea fontana* from northern California. Anderson also introduced the name *Cypraea argonautica* for a specimen from Oregon he had previously identified as *Erato veraghoorensis* Stoliczka, 1867. Most recently, *Cypraea grooti* Richards & Shapiro, 1963, was described from northern Delaware.

Cypraeacean Biogeography

Recent cypraeaceans have their greatest diversity and abundance in warm tropical oceans; warm temperate seas seldom support more than a single species. Cretaceous species ranged as far north as San Juan County, Washington (49°45'N) in North America and Valkenburg, The Netherlands (50°52'N) in Europe. The Cretaceous distribution of cypraeaceans supports the concept of both broad tropical and subtropical to warm-temperate climatic belts (SOHL, 1971).

Mesozoic Cypraeacean Paleontology

The earliest known cypraeaceans, *Palaeocypraea* (*P.*) *tithonica* (Stefano, 1882) and *Bernaya* (*B.*) *gemmellaroi* (Stefano, 1882), are from Upper Jurassic (Tithonian) strata near Termini Imerese, Sicily, Italy. Cretaceous cypraeaceans have been found in Europe, India, South Africa, Iran, North America, and Brazil (SCHILDER & SCHILDER, 1971). SCHILDER & SCHILDER (1971) recognize 69 species of Cretaceous cypraeaceans, 43 of which are from uppermost Cretaceous (Campanian through Maastrichtian)

strata, the cypraeacean Mesozoic peak in terms of both numbers of species and geographic distribution.

Genera and subgenera found in North America are *Palaeocypraea* s.s., *Bernaya* s.s., *Bernaya* (*Protocypraea*), and *Eocypraea* s.s. (Figure 2). *Palaeocypraea* is known from Upper Jurassic (Tithonian) through Upper Paleocene (Thanetian) strata in Europe, South Africa, North America, and Brazil (SCHILDER & SCHILDER, 1971). In the North American Cretaceous it is represented by six species. *Bernaya* s.s. is known from Upper Jurassic (Tithonian) through Lower Oligocene (Lattorfian) strata in Europe, India, Iran, North America, and Brazil (SCHILDER & SCHILDER, 1971). Two species, one of them new, are found in the North American Cretaceous. *Bernaya* (*Protocypraea*) is known from Lower Cretaceous (Barremian) to Recent and is found in Europe, India, Iran, and western North America. *Protocypraea* is represented by a single living species, *Bernaya* (*Protocypraea*) *teulerei* Cazenavette, 1846 (= *Cypraea leucostoma* Gaskoin, 1843, *non* Gmelin, 1791; = *B. (P.) hidalgoi* (Shaw, 1909)) from the Gulf of Oman. *Bernaya* (*P.*) is represented by five species in the Cretaceous of North America, two of which are new. *Eocypraea* s.s. is known from Upper Cretaceous (Cenomanian) through Lower Oligocene (Lattorfian) strata in Europe, India, Iran, New Zealand, South Africa, Indonesia, North America, and South America (SCHILDER & SCHILDER, 1971). Two species of *Eocypraea* s.s., one of them new, are from the Cretaceous of North America.

Abbreviations used for institutional catalogue and lo-

PERIOD	EPOCH	AGE	PICKS (Ma)	PACIFIC COAST	WESTERN INTERIOR AND GULF COAST	ATLANTIC COAST
CRETACEOUS	LATE	MAASTRICHTIAN	88.4			
				<i>B. (B.) crawfordcatei</i> <i>B. (P.) gualalaensis</i> <i>B. (P.) rineyi</i>	<i>E. mortoni</i> <i>P. corsicanana</i> <i>P. nuciformis</i> <i>P. squyeri</i>	
			74.5	<i>P. suclensis</i>	<i>B. (P.) mississippiensis</i>	<i>P. grooti</i>
			64.0			<i>B. (B.) burllingtonensis</i>
		SANTONIAN	87.5			
		CONIACIAN	88.6			
		Turonian		<i>E. lovellae</i> <i>B. (P.) argonautica</i> <i>B. (P.) berryessae</i>		
			91.0			
		CENOMANIAN	97.6			
		ALBIAN		<i>P. fontana</i>		
	EARLY	APTIAN	113.0			
		NEOCOMIAN	119.0 144.0			

Figure 2

Relative chronologic and geographic distribution of North American Cretaceous cypraeids. Picks (Ma) = Radiometric dates (not to scale) from Geological Society of America, Decade of North American Geology [DNAG] time scale.

cality numbers are as follows: ANSP, Academy of Natural Sciences of Philadelphia; CAS, California Academy of Sciences, San Francisco; CIT, California Institute of Technology (collection now at LACMIP); GSC, Geological Survey of Canada, Ottawa; LACMIP, Los Angeles County Museum of Natural History; MGS, Mississippi Geological Survey, Jackson; SDSNH, San Diego Society of Natural History; USGS, United States Geological Survey, Washington; and USNM, National Museum of Natural History, Smithsonian Institution, Washington.

Measurement parameters are defined as follows: length = greatest distance between anterior and posterior ends; width = greatest distance between lateral margins; and height = greatest distance between base and dorsum.

STRATIGRAPHY

Point Loma Formation

The type section for the Point Loma Formation (KENNEDY & MOORE, 1971:711–713) is at Point Loma, San Diego County, California. Its stratigraphic position is near the Campanian/Maastrichtian boundary based upon benthic foraminifera (SLITER, 1968) and mollusks (BANNON *et al.*, 1989). A magnetic reversal in the Point Loma Formation at La Jolla, California, suggests that the formation is mainly early Maastrichtian in age (BANNON *et al.*, 1989). Strata at Carlsbad, California, have been correlated with the Point Loma and La Jolla sections (SLITER, 1968). The mollusks at Carlsbad suggest a more near-shore environment for the Carlsbad strata than for much of the Point Loma and La Jolla strata. Diagnostic molluscan species common to all three areas—*e.g.*, *Baculites lomaensis* Anderson, 1958, *Pachydiscus* (*Neodesmoceras*) *catarinae* (Anderson & Hanna, 1935), and *Perissitys colocara* Popenoe & Saul, 1987—suggest that these sections are of equivalent age. Calcareous nannofossils, benthic foraminifera, and palynomorphs from Carlsbad also sug-

gest a Campanian to Maastrichtian age (M. V. FILEWICZ *et al.*, 1989, personal communication). A 17-m thick section of the Point Loma Formation near Carlsbad consists of shale and interbedded sandstones that contain a diverse and locally rich molluscan fauna (LOCH, 1989). Fossils in the deposit represent a distinct inner shelf assemblage in water less than 140 m deep (SLITER, 1968).

Yolo Formation

The Upper Cretaceous (Turonian), Yolo Formation of KIRBY (1943:285–287) was named for extensive exposures along the west side of the Sacramento Valley in Yolo County, northern California. Petrologic evidence suggests that the randomly interbedded mudstones, shales, and sandstones of the Yolo Formation were deposited as basin-plain turbidite deposits within the Great Valley forearc basin sequence (INGERSOL *et al.*, 1977).

Coffee Formation

The Coffee Formation of the Selma Group was named by SAFFORD (1864:361–363) for exposures at Coffee Landing, Hardin County, Tennessee. Sandstone units in the Tupelo Tongue of the Coffee Formation demonstrate a cyclical sedimentation pattern related to four periods of delta progradation and abandonment (DOCKERY & JENNINGS, 1988). Excavations within the last 15 yr in northeastern Lee County, Mississippi, have exposed very fossiliferous sections of the Upper Cretaceous (Campanian), Coffee Formation (DOCKERY, 1988).

MATERIALS AND METHODS

Thirty-one cypraeacean specimens from the San Diego Society of Natural History, Invertebrate Paleontology collection were borrowed for this project. Two undescribed and one previously described species were determined. A subsequent search of the Los Angeles County Museum of

Natural History, Invertebrate Paleontology collection yielded an additional undescribed species, two specimens of *Bernaya* (*Protocypraea*) *argonautica*, and two cypraeacean fragments of undetermined generic affinity. A fourth undescribed species was borrowed from the Mississippi Geologic Survey. Undescribed specimens were compared to the holotypes of all previously described North American species, which are figured herein for comparison. Comparisons were also made with published illustrations of species from regions other than North America. Matrix from the apertures of several specimens was carefully removed with permission of the lending institutions.

SYSTEMATICS

The classification herein follows that of SCHILDER & SCHILDER (1971) with the exception of the Recent southwestern Australian species *Bernaya catei* Schilder, 1963. BURGESS (1970, 1985) and WALLS (1979) correctly placed *B. catei* in synonymy with *Zoila* (*Zoila*) *venusta* (Sowerby, 1846) based upon similar anatomical and radular characteristics. The genus *Zoila* of JOUSSEAUME (1884), which ranges from the Lower Miocene to the Recent of Australia, India, Indonesia, and Tasmania, may be a descendant of *Bernaya* (WENZ, 1941).

SYSTEMATIC PALEONTOLOGY

Superfamily CYPRAEACEA Rafinesque, 1815

Family CYPRAEIDAE Rafinesque, 1815

Subfamily BERNAYINAE Schilder, 1927

Genus *Palaeocypraea* Schilder, 1928

Type species: *Cypraeacites spiratus* Schlotheim, 1820, by original designation. Lower Paleocene (Danian), Faxø, Denmark.

Diagnosis: Shell small to medium in size, elongated, spire broad and partially covered, aperture wide with deep terminal canals and fine dentition, fossula broad, concave, and smooth.

Subgenus *Palaeocypraea* s.s.

Palaeocypraea (*Palaeocypraea*) *corsicanana*
(Stephenson, 1948)

Figures 3, 4)

Cypraea gracilis STEPHENSON, 1941:314–315, pl. 59, figs. 12–13. Not *Cypraea gracilis* Gaskoin, 1848.

Cypraea corsicanana STEPHENSON, 1948:642 [new name for *Cypraea gracilis* Stephenson, 1941].

Palaeocypraea (*Palaeocypraea*) *squyeri corsicanana* (Stephenson, 1948: SCHILDER & SCHILDER, 1971:25, 107.

Type material: Holotype, USNM 20894. The holotype measures 14.2 mm in length, 10 mm in width, and 7.8 mm in height.

Type locality: USGS loc. 518, near Postoak Creek, north edge of Corsicana, Navarro County, Texas. Upper Cretaceous (Maastrichtian), Nacatoch Sand, Navarro Group.

Remarks: *Palaeocypraea squyeri* (Campbell, 1893) has deeper terminal canals and is more elongate than *Palaeocypraea corsicanana*, and should be considered a separate species.

Palaeocypraea (*Palaeocypraea*) *fontana*
(Anderson, 1958)

(Figures 5, 6)

Cypraea fontana ANDERSON, 1958:177, pl. 21, figs. 15, 16.

Palaeocypraea (*Palaeocypraea*) *korycanensis fontana* (Anderson, 1958): SCHILDER & SCHILDER, 1971:25, 116.

Type material: Holotype, CAS 1345.04. The holotype measures 27.8 mm in length, 16.8 mm in width, and 11.1 mm in height.

Type locality: CAS loc. 1345, Texas Springs, 3.2 km east of Horsetown, on road leading to Centerville, Shasta County, California. Lower Cretaceous (uppermost lower Albian) (L. R. Saul, 1989, personal communication), Budden Canyon Formation.

Remarks: *Palaeocypraea korycanensis* (Weinzettl, 1910) from Korycan, Czechoslovakia, is more elongate and less globose than *Palaeocypraea fontana* (Anderson, 1958) and is considered a separate species. *Palaeocypraea fontana* is the earliest cypraeacean found in the Western Hemisphere.

Palaeocypraea (*Palaeocypraea*) *grooti*
(Richards & Shapiro, 1963)

(Figures 7, 8)

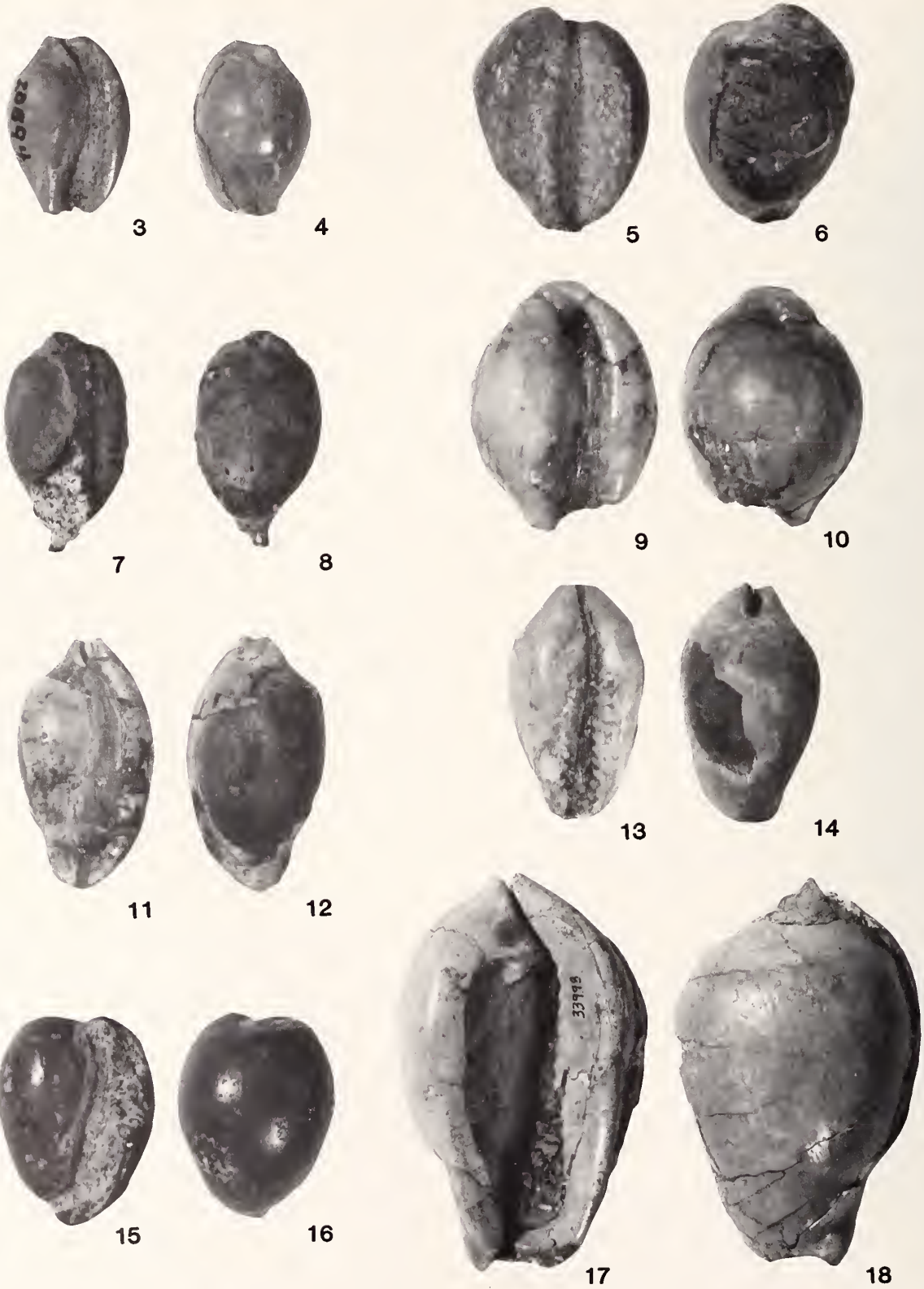
Cypraea grooti RICHARDS & SHAPIRO, 1963:12, pl. 4, fig. 3a–c; RICHARDS, 1968:140; OWENS *et al.*, 1970:45.

Palaeocypraea (*Palaeocypraea*) *squyeri grooti* (Richards & Shapiro, 1963): SCHILDER & SCHILDER, 1971:25, 120.

Type material: Holotype, ANSP 30838. The holotype measures 17.5 mm in length, 10.1 mm in width, and 7.9 mm in height.

Type locality: Station 6 of GROOT *et al.* (1954), Biggs Farm, south bank Chesapeake and Delaware Canal, 2.41 km east of crossing of U.S. Highway 13 and the canal at St. Georges, New Castle County, Delaware. Upper Cretaceous (lower Maastrichtian), Mt. Laurel-Navesink Formation.

Remarks: Represented by a single poorly preserved internal mold that does not resemble *Palaeocypraea squyeri* (Campbell, 1893). *Palaeocypraea grooti* is more globose and less elongate than *P. squyeri* and, although treated as a subspecies of the latter by SCHILDER & SCHILDER (1971: 25), they are considered separate species.



Palaeocypraea (Palaeocypraea) nuciformis
(Stephenson, 1941)

(Figures 9, 10)

Cypraea nuciformis STEPHENSON, 1941:314, pl. 59, figs. 8 (holotype), 10–11 (paratypes).

Palaeocypraea (Palaeocypraea) suecica nuciformis (Stephenson, 1941): SCHILDER & SCHILDER, 1971:25, 138.

Type material: Holotype, USNM 76988, and two paratypes, USNM 21007. The holotype measures 24 mm in length, 18.1 mm in width, and 14.7 mm in height.

Type locality: USGS loc. 761, in the vicinity of Kaufman, Kaufman County, Texas. Upper Cretaceous (Maastrichtian), Nacatoch Sand, Navarro Group.

Remarks: The holotype and two paratypes are from the same locality. *Palaeocypraea nuciformis* has a wider aperture and is more globose than *P. suecica* Schilder, 1928, from Denmark and they are considered separate species.

Palaeocypraea (Palaeocypraea) squyeri
(Campbell, 1893)

(Figures 11, 12)

Cypraea squyeri CAMPBELL, 1892:50–51, *nomen nudum*.

Cypraea squyeri CAMPBELL, 1893:52, pl. 2, figs. 1, 2; INGRAM, 1942:16, pl. 3, figs. 3, 4; INGRAM 1947a:59–60, pl. 2, figs. 11, 12; INGRAM, 1947b:13; RICHARDS, 1968:190.

Palaeocypraea squyeri (Campbell, 1893): SCHILDER, 1932:110.

Palaeocypraea (Palaeocypraea) squyeri (Campbell, 1893): SCHILDER & SCHILDER, 1971:25, 157.

Type material: Holotype, ANSP 13536. The holotype measures 20.1 mm in length, 11 mm in width, and 8.9 mm in height.

Type locality: Near Mingusville (now Wibaux), Dawson County (now in Wibaux County), Montana. Upper Cretaceous (Maastrichtian), Fox Hills Formation.

Remarks: This species is represented only by the well preserved holotype. *Palaeocypraea squyeri* is similar to *P. suciensis* (Whiteaves, 1895), but is more elongate and has

a shallower posterior terminal canal than the latter, and should be considered a separate species.

Palaeocypraea (Palaeocypraea) suciensis
(Whiteaves, 1895)

(Figures 13, 14)

Cypraea suciensis WHITEAVES, 1895:127–128, pl. 3, fig. 5;

WHITEAVES, 1903:357; WHITNEY, 1928:154; INGRAM, 1942:16; INGRAM, 1947a:60–61; INGRAM, 1947b:13; BOLTON, 1965:15.

Palaeocypraea suciensis (Whiteaves, 1895): SCHILDER, 1932:110.

Palaeocypraea (Palaeocypraea) squyeri suciensis (Whiteaves, 1895): SCHILDER & SCHILDER, 1971:25, 160.

Type material: Holotype, GSC 5937. The holotype measures 19.5 mm in length, 11.9 mm in width, and 9.5 mm in height.

Type locality: Sucia Island, San Juan County, Washington. Upper Cretaceous (lower late Campanian), Cedar District Formation, Nanaimo Group.

Remarks: This species is based only on the well preserved holotype. *Palaeocypraea suciensis* differs from *P. squyeri* (Campbell, 1893) by its less elongate shell and deeper posterior terminal canal, and should be considered a separate species.

Genus *Bernaya* Jousseaume, 1884

Type species: *Cypraea media* Deshayes, 1835, by original designation. Upper Middle Eocene (Bartonian Stage), Auvvers-sur-Oise, Val-d'Oise (northwest of Paris).

Diagnosis: Shell medium to large size, anterior end somewhat carinate, dorsum smooth, spire of medium height and partially covered, aperture wide, sides rounded, anterior and posterior canals deep, fossula smooth, concave, wide.

Subgenus *Bernaya* s.s.

Diagnosis: Shell more elongate and aperture less sinuous than in *Bernaya (Protocypraea)*.

Explanation of Figures 3 to 18

Figures 3, 4. *Palaeocypraea (Palaeocypraea) corsicanana* (Stephenson, 1948), holotype, USNM 20894, from USGS loc. 518, $\times 2.0$. Figures 5, 6. *Palaeocypraea (Palaeocypraea) fontana* (Anderson, 1958), holotype, CAS 1345.04, from CAS loc. 1345, $\times 1.3$. Figures 7, 8. *Palaeocypraea (Palaeocypraea) grooti* (Richards & Shapiro, 1963), holotype, ANSP 30838, from station 6 of GROOT *et al.* (1954), $\times 2.0$. Figures 9, 10. *Palaeocypraea (Palaeocypraea) nuciformis* (Stephenson, 1941), holotype, USNM 76988, from USGS loc. 761, $\times 1.7$. Figures 11, 12. *Palaeocypraea (Palaeocypraea) squyeri* (Campbell, 1893), holotype, ANSP 13536, from Mingusville (now Wibaux), Montana, $\times 2.0$. Figures 13, 14. *Palaeocypraea (Palaeocypraea) suciensis* (Whiteaves, 1895), holotype, GSC 5937, from Sucia Island, Washington, $\times 2.0$. Figures 15, 16. *Bernaya (Bernaya) burlingtonensis* (Schilder, 1932), holotype, ANSP 13537, from Burlington County, New Jersey, $\times 2.0$. Figures 17, 18. *Bernaya (Bernaya) crawfordcatei* sp. nov., holotype, SDSNH 33998, from SDSNH loc. 3392, $\times 0.9$.

Bernaya (Bernaya) burlingtonensis
(Schilder, 1932)

Figures (15, 16)

Cypraea (Aricia) mortoni Gabb, 1860: GABB, 1861:104 [in part]; WHITFIELD, 1892a:120, 291, pl. 15, figs. 1–3; WHITFIELD, 1892b:120, 291, pl. 15, figs. 1–3; WHITNEY, 1928:154. Not *Cypraea mortoni* Gabb, 1860 [= *Eocypraea (E.) mortoni* (Gabb), *q.v.*].

Cypraea mortoni Gabb, 1860: MEEK, 1864:19 [in part]; COOK, 1868:729; JOHNSON, 1905:23; WELLER, 1907:722–723 [in part], pl. 84, figs. 1–2; WHITNEY, 1928:154 [in part]; RICHARDS & RAMSDELL, 1962:47, pl. 53, fig. 9, pl. 64, fig. 6. Not *Cypraea mortoni* Gabb, 1860.

Palaeocypraea burlingtonensis SCHILDER, 1932:111 [new name for *Cypraea "mortoni"* of Gabb, 1861]; SCHILDER, 1958: 162.

Cypraea cf. C. mortoni Gabb, 1860: OWENS *et al.*, 1970:42. Not *Cypraea mortoni* Gabb, 1860.

Bernaya (Bernaya) burlingtonensis (Schilder, 1932): SCHILDER & SCHILDER, 1971:26, 101.

Type material: Holotype, ANSP 13537. The holotype measures 16.5 mm in length, 12.9 mm in width, and 9.6 mm in height.

Type locality: Burlington County, New Jersey. Upper Cretaceous (upper Campanian), Mt. Laurel-Navesink Formation.

Remarks: *Bernaya (B.) burlingtonensis* is represented by at least three specimens. An internal mold was figured by WHITFIELD (1892a, b) as *Cypraea (Aricia) mortoni* Gabb, 1860. Based upon a comparison to the ANSP specimen, this is the holotype. A second specimen was illustrated by WELLER (1907) as *Cypraea mortoni* Gabb from Atlantic Highlands, Monmouth County, New Jersey. A third specimen was collected from the Upper Cretaceous (Campanian) Marshalltown Formation (USGS loc. 17702) by C. W. Carter (OWENS *et al.*, 1970) near the Chesapeake and Delaware Canal, New Castle County, Delaware. SCHILDER (1932) separated these Campanian specimens—previously identified with *Cypraea mortoni*, the Maastrichtian species—based on a similar, but less globose, internal mold from Prairie Bluff, Alabama.

Bernaya (Bernaya) crawfordcatei Groves, sp. nov.

(Figures 17, 18)

Diagnosis: A *Bernaya* of large size, anterior and posterior canals deep, spire of medium height, fossula smooth concave, anterior and posterior terminal ridges prominent extending to margins.

Description: Shell large, somewhat constricted anteriorly; maximum height and width posterior to center; spire of medium height, partially covered; dorsum somewhat flattened; aperture wide, slightly S-shaped; denticulation coarse, with smooth interstices, outer lip with 16 teeth that become stronger posteriorly; outer lip with prominent anterior and posterior terminal ridges extending to anterior and posterior margins; posterior terminal ridge extending

to base of spire; anterior terminal ridge forming slight marginal callus.

Comparison: The new species most similar to *Bernaya (Protocypraea) gualalaensis* (ANDERSON, 1958:176, pl. 63, fig. 2–2b) from the Upper Cretaceous (lower Maastrichtian), Gualala Group, Mendocino County, California. *Bernaya (B.) crawfordcatei* differs from *B. (P.) gualalaensis* by its larger size, coarser denticulation, wider base, terminal ridges that do not extend onto the spire, slight anterior marginal callus, deeper anterior and posterior canals, and a gently sloping anterior profile.

Discussion: Post-depositional crushing has damaged the fossula and inner lip dentition. Generic and subgeneric assignment are based on its large size, wide aperture, deep anterior and posterior terminal canals, and spire of medium height. *Bernaya (B.) crawfordcatei* is much larger than other North American Cretaceous cypraeaceans and exceeds the next largest species, *B. (Protocypraea) gualalaensis* (Anderson, 1958), by 22 mm in length.

Material: The new species is represented by two specimens. The holotype is slightly crushed, but otherwise well preserved. A second specimen is a poorly preserved internal mold with minor amounts of original shell material.

Type material: Holotype, SDSNH 33998. The holotype measures 72.9 mm in length, 45.8 mm in width, and 30.2 mm in height.

Type locality: SDSNH loc. 3392, near Carlsbad, northern San Diego County, southern California. Upper Cretaceous (Campanian/Maastrichtian), Point Loma Formation.

Etymology: The species is named in honor of the late Crawford N. Cate, in recognition of his valuable contributions to cypraeacean studies.

Subgenus *Protocypraea* Schilder, 1927

Type species: *Eocypraea orbignyana* Vredenburg, 1920, by original designation. Upper Cretaceous (Turonian through Santonian), Trichinopoly Group, Kullygoody, southern India.

Diagnosis: Shell small to medium in size, shape moderately pyriform, somewhat constricted anteriorly, fossula smooth, concave, wide.

Bernaya (Protocypraea) argonautica
(Anderson, 1958)

(Figures 19, 20)

Erato vergahooënsis [sic] (?) Stol. [iczka, 1867]: ANDERSON, 1902:75–76, pl. 9, figs. 181, 182. Not *Erato veraghoorensis* Stoliczka, 1867 [= *Bernaya (P.) veraghoorensis*].

Cypraea argonautica ANDERSON, 1958:177, pl. 21, fig. 4–4a. *Bernaya (Protocypraea) argonautica* (Anderson, 1958): SCHILDER & SCHILDER, 1971:26, 96.

Type material: Holotype, CAS 61856.05 [ex CAS 42]. The holotype is a partially pyritized specimen that mea-

asures 21.5 mm in length, 19 mm in width, and 13.6 in height. The holotype was damaged in the 1906 San Francisco fire, but was recovered and preserved in the CAS Type Collection as CAS 42 (ANDERSON, 1958).

Type locality: CAS loc. 61856 [ex CAS loc. 445-A], Fitch Ranch (formerly Smith Ranch), 3.2 km west of Phoenix, Jackson County, Oregon. Upper Cretaceous (Cenomanian or lower Turonian) (L. R. Saul, 1989, personal communication), Blue Gulch Member, Hornbrook Formation.

Remarks: Two specimens of *Bernaya* (*P.*) *argonautica* from LACMIP loc. 10903 are from the Turonian, near Ashland, Jackson County, Oregon. Although similar, *B.* (*P.*) *veraghoorensis* (Stoliczka, 1867) from southern India is more elongate than *B.* (*P.*) *argonautica*, and is treated as a separate species.

Bernaya (*Protocypraea*) *berryessae*
(Anderson, 1958)

(Figures 21, 22)

Cypraea berryessae ANDERSON, 1958:176, pl. 63, fig. 2-2b.

Bernaya (*Protocypraea*) *berryessae* (Anderson, 1958): SCHILDER & SCHILDER, 1971:26, 99.

Type material: Holotype, CAS 31918.02 [ex CAS 10677]. The holotype measures 18 mm in length, 13.1 mm in width, and 9.8 mm in height.

Type locality: CAS loc. 31918, Thompson Canyon area, Yolo County, northern California. Upper Cretaceous (Turonian), Yolo Formation (POPENOE *et al.*, 1987).

Remarks: Two well preserved topotypes were also examined.

Bernaya (*Protocypraea*) *gualalaensis*
(Anderson, 1958)

(Figures 23-26)

Cypraea gualalaensis ANDERSON, 1958:176, pl. 62, fig. 8-8a.

Bernaya (*Protocypraea*) *kayei gualalaensis* (Anderson, 1958): SCHILDER & SCHILDER, 1971:26, 120.

Cypraea guadelensis [sic] Anderson, 1958: SUNDBERG & RINEY, 1984:105, fig. 3, no. 6.

Type material: Holotype, CAS 61918.01 [ex CAS 10679]. The holotype measures 50.2 mm in length, 32.4 mm in width, and 22.1 mm in height.

Type locality: CAS loc. 61918 [ex S. G. Clark loc. 251], near Gualala, Mendocino County, California. Upper Cretaceous (lower Maastrichtian), Gualala Group.

Remarks: This species is represented by a somewhat well preserved holotype and 23 specimens from the Upper Cretaceous (Campanian/Maastrichtian), Point Loma Formation, SDSNH locs. 3162, 3162-A, 3162-B, 3162-M, 3392, 3405, and 3454 near Carlsbad, San Diego County, California. The specimen figured by SUNDBERG & RINEY (1984:105, fig. 3, no. 6), SDSNH 25947, measures 36.7

mm in length, 22.3 mm in width, and 19.4 mm in height. Another specimen from Carlsbad (Figures 25, 26) measures 38.4 mm in length, 23.6 mm in width, and 19 mm in height. The Carlsbad specimens are excellently preserved and display original shell material. *Bernaya* (*Protocypraea*) *kayei* (Forbes, 1846) from southern India, is similar to *B.* (*P.*) *gualalaensis* but is more globose and less elongate, and is treated here as a separate species.

Bernaya (*Protocypraea*) *mississippiensis* Groves, sp. nov.
(Figures 27, 28)

Bernaya (*s.l.*) new species: DOCKERY, 1988:19, fig. 3.

Diagnosis: Pyriform *Protocypraea*, anterior and posterior basal terminal ridges prominent, fossula, concave, smooth.

Description: Shell moderately inflated, slightly elongate, of small size, constricted anteriorly; spire covered, dorsum moderately arched; maximum height near midpoint of shell; maximum width slightly posterior of center; aperture slightly S-shaped, denticulation fine with smooth interstices, outer lip with 20 teeth, inner lip with 17 teeth; fossula smooth and concave; all surfaces smooth and glossy; anterior and posterior basal terminal ridges prominent; anterior and posterior terminal canals deep.

Comparison: The new species is most similar to *Bernaya* (*Protocypraea*) *rineyi* sp. nov. from the Upper Cretaceous (Campanian/Maastrichtian), Point Loma Formation, San Diego County, southern California, and to *Eocypraea newboldi* (FORBES, 1846:134, pl. 12, fig. 121) from the Upper Cretaceous (Turonian through Santonian) Trichinopoly Group of southern India. *Bernaya* (*P.*) *mississippiensis* differs from both in having more numerous apertural teeth, deeper anterior and posterior terminal canals, a less inflated dorsum, and prominent anterior and posterior basal terminal ridges.

Discussion: The excellent preservation allows for unequivocal generic and subgeneric assignment. *Bernaya* (*P.*) *mississippiensis* is quite different from other Cretaceous cypraeids from the Gulf Coast region of the United States and is the first cypraeacean species reported from the upper reaches of the Mississippi Embayment (DOCKERY, 1988).

Material: Represented by the well preserved holotype and a sub-adult paratype, both of which display original shell material.

Type material: Holotype USNM 446797, paratype USNM 446798. The holotype measures 21.5 mm in length, 13.7 mm in width, and 9.8 mm in height. The paratype measures 15.9 mm in length, 10.5 mm in width, and 8.4 mm in height.

Type locality: MGS loc. 129, northern Lee County, Mississippi. The holotype and paratype were collected from the Upper Cretaceous (Campanian), "Chapelville fossiliferous horizon" within the Tupelo Tongue sequence of the Coffee Formation near Chapelville, Mississippi.



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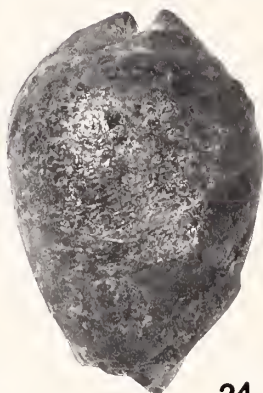
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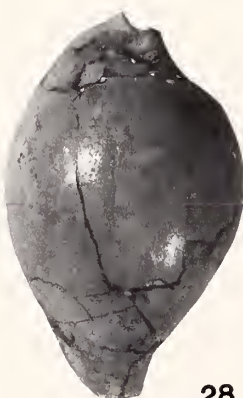
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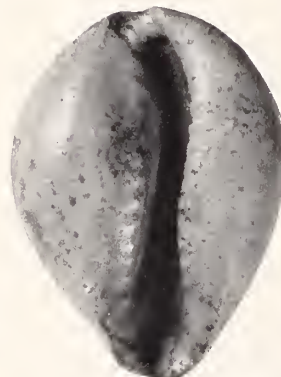
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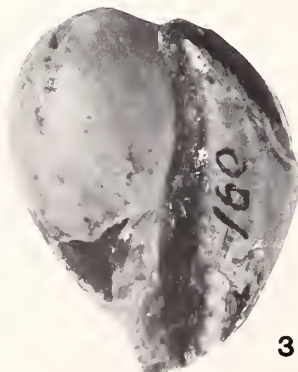
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Etymology: This species is named after the state of Mississippi.

Bernaya (Protocypraea) rineyi Groves, sp. nov.

(Figures 29, 30)

Diagnosis: Pyriform *Protocypraea*, anterior and posterior canals shallow, aperture slightly S-shaped, fossula, smooth, concave.

Description: Shell inflated-pyriform, of small size, constricted anteriorly; spire nearly covered; dorsum highly arched; maximum height near midpoint of shell; maximum width posterior of center; aperture slightly S-shaped, narrowing near midpoint and widening toward anterior end; denticulation coarse with smooth interstices, outer lip with 13 teeth that increase in strength posteriorly, inner lip with 12 teeth; fossula concave, smooth, wide; anterior and posterior terminal canals shallow; all surfaces smooth and glossy.

Comparison: The new species is most similar to *Bernaya (Protocypraea) berryessae* (ANDERSON, 1958:176, pl. 65, fig. 2-2b) from the lower Upper Cretaceous (Turonian) of Yolo County, California, but differs from the latter by its smaller size, wider, slightly S-shaped aperture, shallower anterior and posterior canals, and fewer teeth on the outer and inner lips.

Discussion: The excellent preservation displayed in the holotype allows for unequivocal generic and subgeneric assignments. Not only is *Bernaya (Protocypraea) rineyi* different from all other Cretaceous cypraeaceans from North America, but it is much younger than any similar species.

Material: Six specimens include the excellently preserved complete holotype, four poorly preserved crushed, incomplete specimens, and a single posterior fragment. All specimens appear to display original shell material.

Type material: Holotype, SDSNH 34008. The holotype measures 12.3 mm in length, 9.1 mm in width, and 7.1 mm in height.

Type locality: The holotype is from SDSNH loc. 3392 and the other specimens are from SDSNH locs. 3162-B and 3392. All of the specimens were collected from the Upper Cretaceous (Campanian/Maastrichtian), Point Loma Formation, near Carlsbad, northern San Diego County, California.

Etymology: This species is named after Bradford O. Riney (SDSNH) who collected not only the holotype, but numerous important fossils from southern California and northern Baja California, Mexico.

Family OVULIDAE Fleming, 1828

Subfamily EOCYPRAEINAE Schilder, 1924

Genus *Eocypraea* Cossmann, 1903

Type species: *Cypraea inflata* Lamarck, 1802, by original designation. Middle Eocene (Lutetian-Bartonian Stages), Paris Basin, France.

Diagnosis: Inflated-pyriform shell of small to medium size; spire involute; narrow elongate aperture; fossula broad, smooth, concave.

Subgenus *Eocypraea* s.s.

Eocypraea (Eocypraea) louellae Groves, sp. nov.

(Figures 31, 32)

Diagnosis: An *Eocypraea* with highly inflated shell, coarse denticulation, and slightly S-shaped aperture.

Description: Shell highly inflated, of small size, constricted anteriorly; spire partially covered; dorsum highly arched; maximum height slightly posterior of center; maximum width posterior of center; aperture slightly S-shaped; denticulation coarse with smooth interstices; outer lip with two teeth; fossula smooth, concave; all surfaces smooth, glossy; posterior columella highly inflated; anterior and posterior terminal canals shallow.

Comparison: The new species is most similar to *Eocypraea newboldi* (FORBES, 1846:134, pl. 12, fig. 21) from Upper Cretaceous (Turonian through Santonian), Trichinopoly

Explanation of Figures 19 to 34

Figures 19, 20. *Bernaya (Protocypraea) argonautica* (Anderson, 1958), holotype, CAS 61856.05, from CAS loc. 61856, $\times 2.0$. Figures 21, 22. *Bernaya (Protocypraea) berryessae* (Anderson, 1958), holotype, CAS 31918.02, from CAS loc. 31918, $\times 2.0$. Figures 23, 24. *Bernaya (Protocypraea) gualalaensis* (Anderson, 1958), holotype, CAS 61918.01, from CAS loc. 61918, $\times 1.0$. Figures 25, 26. *Bernaya (Protocypraea) gualalaensis* (Anderson, 1958), hypotype, SDSNH 33995, from SDSNH loc. 3405, $\times 1.3$. Figures 27, 28. *Bernaya (Protocypraea) mississippiensis* sp. nov., holotype, USNM 446797, from MGS loc. 129, $\times 2.5$. Figures 29, 30. *Bernaya (Protocypraea) rineyi* sp. nov., holotype, SDSNH 34008, from SDSNH loc. 3392, $\times 3.9$. Figures 31, 32. *Eocypraea (Eocypraea) louellae* sp. nov., holotype, LACMIP 8281, from LACMIP loc. 28757, $\times 3.0$. Figures 33, 34. *Eocypraea (Eocypraea) mortoni* (Gabb, 1860), holotype, ANSP 13535, from Prairie Bluff, Alabama, $\times 2.0$.

Group, southern India, but differs from the latter by its highly inflated posterior columella, coarser denticulation, less sinuous aperture, and larger size.

Discussion: Good preservation of the holotype permits unequivocal generic and subgeneric assignments. *Eocypraea louellae* differs from all other Cretaceous cypraeaceans of North America, and is the earliest known ovulid from the Western Hemisphere.

Material: This species is represented by the well preserved holotype that displays original shell material. A second specimen from the Upper Cretaceous (Cenomanian to Turonian) Hornbrook Formation of Jackson County, Oregon, UCLA loc. 7288, is an internal mold with minor amounts of original shell material.

Type material: Holotype LACMIP 8281. The holotype measures 15.5 mm in length, 12.3 mm in width, and 9.7 mm in height.

Type locality: LACMIP loc. 28757, Putah Creek area of Thompson Canyon, Yolo County, northern California. Upper Cretaceous (Turonian), Yolo Formation.

Etymology: This species is named for Louella R. Saul (LACMIP) in recognition of her numerous important contributions to Cretaceous and Tertiary molluscan paleontology.

Eocypraea (Eocypraea) mortoni (Gabb, 1860)

(Figures 33, 34)

C. [ypraea] mortoni GABB, 1860:391, pl. 68, fig. 9 [not fig. 8].
Cypraea mortoni Gabb, 1860: GABB, 1861:104 [in part]; MEEK, 1864:19 [in part]; WELLER, 1907:722 [in part]; WHITNEY, 1928:154 [in part]; RICHARDS, 1968:162.

Eocypraea (Eocypraea) mortoni (Gabb, 1860): SCHILDER, 1932: 213; SCHILDER, 1941:102; SCHILDER & SCHILDER, 1971: 67, 135.

Type material: Holotype, ANSP 13535. The holotype measures 17.4 mm in length, 13.9 mm in width, and 11.9 mm in height.

Type locality: Prairie Bluff, Wilcox County, Alabama. Upper Cretaceous (Maastrichtian), Prairie Bluff Formation.

Remarks: *Eocypraea mortoni* is represented by a single poorly preserved internal mold that displays few identifiable shell characters. Schilder (1932) separated material from Prairie Bluff, Alabama, and Burlington County, New Jersey, assigning those from New Jersey to *Palaeocypraea burlingtonensis*. *Eocypraea mortoni* is more globose than *Bernaya (Protocypraea) burlingtonensis*.

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